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MODELING OF THE DEPENDENCE OF THE PRODUCED AMOUNT OF HYDROGEN GAS (Y) ON THE AMPERAGE OF CELL (X) OF A MARINE DIESEL ENGINE SKL 3NVD24

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Abstract. The introduction of new fuels in the field of maritime transport is considered a serious challenge due to the harsh environmental conditions in which the motor ship must operate. Modern marine engines are designed to improve the overall efficiency of the marine system so any attempt to exploit a new fuel must be accompanied by scientific research and experimental data to provide engineers and ship operators with sufficient information on its efficiency and safety.
Keywords: marine engine; hydrogen; dependence hydrogen gas

Introduction

The purpose of this publication is to present the results of a study on the impact of hydrogen gas on the environmental characteristics of the exhaust gases of a marine diesel engine SKL 3NVD24. Place of the experiment – Naval Academy – „N. Vaptsarov" – Varna.

Objective and research methodologies

The engine used is four stroke inline, atmospherically charged. Piston stroke – 240 mm and cylinder diameter – 175 mm. The designation 3NVD24 indicates that the engine is 3 cylinder, N – means that the ratio of stroke of the piston to the diameter of cylinder – is less than 1.3. The letter sign V – indicates that the engine is four-stroke and D – means that it is a diesel engine. The number after designation is the stroke of the piston in centimeters. The SKL 3NVD24 engine was manufactured in 1965 at the Karl Liebkner plant in Magdeburg in the former German Democratic Republic.

The engine's fuel system includes fuel filters, fuel pumps (one for each cylinder) and fuel valves. The engine oil system includes a crankshaft gear oil pump, coarse and fine filters and a double acting manual piston pump for pre-coupling oil to the main and connection rod bearings. The cooling system consists of two circuits, an open circuit in which the circulation of sea water is simulated and a closed circuit with fresh water. If the cooling circuit with fresh water is damaged, the engine can also be cooled with sea water from the open circuit.

A piston pump provides the incoming water to the open cooling circuit and a centrifugal pump provides cooling of the cylinder block and the cooling spaces of the cylinder head through water-water cooler. Both pumps are driven by the crankshaft via a gear drive. The engine is started with the help of compressed air at a nominal pressure of 30 bar and a minimum rotation pressure of 12 bar. The nominal speed is 600 min^{-1} and the minimum speed is 300 min^{-1}. The rated power of the engine is 44.1 kW or 60 hP. The working volume of the cylinders is 17.32 dm^3 (5.76 dm^3 for each cylinder). Stand KI2139B-GOSNITI is designed for testing engines with nominal torque of 25-40 kg/m and crankshaft speed of 1500-3000 min^{-1}. As the operating frequency of the engine is 300-600 min^{-1}, to work together with the electric brake, an increasing gear is required. For this purpose, a multiplier with a gear ratio of 1:5 is installed. The supply voltage of the stand is 380V, the frequency is 50 Hz. The load capacity of the stand is 210kW. The breaking and torque measuring device is a pendulum-type weighing mechanism.

Figure 1. Marine diesel engine SKL3NVD24

Figure 2. Gas generator

The hydrogen experiment was performed on a VST 4C gas generator, manufactured by Hydrogas. This machine is an oxy-hydrogen gas generator. It produces stoichiometric gas mixture composed of hydrogen and oxygen. The gas mixture is a useful product which in turn is used to clean international combustion engines of any type, size, power, fuel and purpose. The VST-4C is automatic and the operator must set the operating mode limits by providing a front-facing display for this purpose performing command and control functions. The gas generator is designed in accordance with the latest technologies and requirements for this type of machine. Its work is completely reliable and safe.

In Table 1. the technical characteristics of the gas generator can be seen.

Table 1. Technical characteristics of the gas generator

Model VST 4C	
maximum installed power /KW/	6
maximum gas productivity (litres/hour)	6500
maximum consumption of distilled water (liters/hour)	0,5
weight /kilograms/	150
dimensions /mm/	600/1480/600

The experiment was performed while maintaining the same engine temperature with a change in the amount of gas supplied (by changing the current of the hydrogen cell) and registration of components of the exhaust gases (Liang et al. 2017). The experiment is performed at rated speed and without load. It is necessary to specify that all tests and the accompanying conclusions refer only to the specific type of hydrogen cell and the respective engine (Miller et al. 2014; Miao et al. 2021; Sapra et al. 2020). Their summary in different conditions can only be of a principled nature.

In the performed research, a significant difference in the data was found, due to the selected factors and external disturbances (Bakalova et al. 2020). An experimental statistical method – regression analysis was chosen for processing the experimental material. Excerpts from 9 experiments were used. Obtaining qualitative regression models was achieved after performing the following two step procedure: determining the parameters of a pre-selected structure of the model and statistical analysis of the results (Bakalova 2020). The finally selected model can be used to predict the effect of the fuel-hydrogen mixture on the exhaust components (Li et al. 2019). Due to the nature of the operation of the hydrogen cell at the beginning of the study, a regression dependence of the change in the amount of hydrogen gas on the strength of the electric current was obtained (Feili et al. 2020). In all subsequent studies, the amount of hydrogen gas was taken as a factor and the content of gases was taken as a starting point. The results of the research are presented in Tab 2.

Table 2. Exhaust gas content depending on the amount of hydrogen gas.

dimension	I try	II try	III try	IV try	V try	VI try	VII try	VIII try	IX try
amperage (A)	40	50	60	70	80	90	100	110	120
gas	3	3.3	3.2	3.6	4.3	4.3	4.8	5	5.1
diesel	36	38	33	38	39	40	37	38	42
CO	14.45	14.49	16.4	16.5	16.7	16.8	17	17.1	17.2
CO_2	2.4	2.4	2.3	2.4	2.4	2.5	1.7	1.8	1.7
NO	150	152	90	106	111	118	77	77	80
O_2	17.8	17.8	18	17.9	17.8	17.7	18.7	18.7	18.6
NO_x	150	152	90	106	111	118	77	77	80
qA	44.2	46.1	37.3	39.5	41.5	45.7	52.6	58.3	59.1
Eta	55.8	53.9	62.7	60.5	58.5	54.3	47.4	41.7	40.9

Table 3. presents the amount of hydrogen gas depending on the amperage of the cell.

Table 3. Amount of hydrogen gas depending on the amperage of the cell

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amperage (A)	40	50	60	70	80	90	100	110	120
gas	3	3.3	3.2	3.6	4.3	4.3	4.8	5	5.1
diesel	36	38	33	38	39	40	37	38	42
CO	14.45	14.49	16.4	16.5	16.7	16.8	17	17.1	17.2
CO_2	2.4	2.4	2.3	2.4	2.4	2.5	1.7	1.8	1.7
NO	150	152	90	106	111	118	77	77	80
O_2	17.8	17.8	18	17.9	17.8	17.7	18.7	18.7	18.6
NO_x	150	152	90	106	111	118	77	77	80
qA	44.2	46.1	37.3	39.5	41.5	45.7	52.6	58.3	59.1
Eta	55.8	53.9	62.7	60.5	58.5	54.3	47.4	41.7	40.9

The results of the application of the regression analyses are given in Table 4.

Table 4. Results obtained from mathematical modeling

dependence modeling results – amount of hydrogen gas (y) of amperage (x) ; y=f(x)						
type of model	coefficient of the model	adequacy of the model	standard error S_y	coefficient of correlation	correlation of the remains	stationarity of the disp.
$y=b_0+b_1x$	b_0=1.7467 b_1=0.029	yes	0,18283	0,9776	No	yes
$y=b_0+b_1x+b_2x^2$	b_0=1.7839 b_1=0.028 b_2=0.65e-005	yes	0,19743	0,9776	No	yes
$y=b_0+b_1\ln x$	b_0=5.0365 b_1= 2.1051	yes	0,23873	0,96148	No	No
chosen model	y=1.7467+0.029x					

The analysis of the data shows that the linear model is adequate. It gives minimal standard error, high correlation coefficient and satisfaction of the conditions for application of the regression analysis – absence of correlation of the residues, constant value of the variance, normal distribution of the residues e_i and $\sum e_i \equiv -2.0872e-014$, value accepted for zero. It is finally selected to approximate the data and the amount of hydrogen gas produced by the cell current. The following graph compares the actual experimental data (*) and those obtained from the model (-).

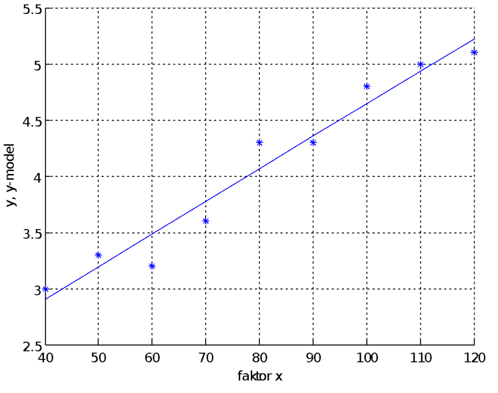

Figure 3. Comparison between experimental data (*) and obtained model (-)

Conclusions

From the obtained results we can draw the following conclusions:

– Carbon fuel is a good option to replace fuel oil and diesel fuel, which are currently used in marine diesel engines.

– The use of hydrogen fuel can reduce greenhouse gas emissions due to the lower levels of harmful emissions from the use of hydrogen fuel (as shown by experiments)

– The use of hydrogen for maritime purposes will have an impact on reducing global warming and will also have an impact on the eco-toxicity of the environment and sediments in seawater.

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